GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

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Date: September 30, 1976

Project Title: Radar-RADAC Interface

Project No: A-1897 (Sub-project under E-21-A00/School of EE/Paris)

Project Director: Mr. P. H. Ryan, Jr.

Sponsor: Naval Coastal Systems Laboratory; Panama City, Florida 32401

Agreement Period: From 9/7/76 Until 6/10/77

Type Agreement: Contract No. N61339-75-C-0122; Delivery Order No. HR-20

Amount: $57,574

Reports Required: Monthly Progress Letters; Final Technical Report

Sponsor Contact Person (s):

Technical Matters	Contractual Matters (thru OCA)
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Defense Priority Rating: DO-A7 under DMS Reg. 1

Assigned to: Systems and Techniques Laboratory (School/Laboratory)

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CA—3 (3/76)

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: November 17, 1977

Project Title: Radar-RADAC Interface

Project No: A-1897 (Sub-project under E-21-A00/School of EE)

Project Director: Mr. P. H. Ryan, Jr.

Sponsor: Naval Coastal Systems Laboratory; Panama City, FL 32401

Effective Termination Date: 11/10/77 (Delivery Required)

Clearance of Accounting Charges: 11/30/77

Grant/Contract Closeout Actions Remaining:

x Final Invoice ~~and Closing Documents~~

_ Final Fiscal Report

x Final Report of Inventions

x Govt. Property Inventory & Related Certificate

_ Classified Material Certificate

_ Other ____________

Assigned to: Radar Instrumentation Laboratory (School/Laboratory)

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ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

November 15, 1976

Commanding Officer
Naval Coastal Systems Laboratory
Panama City, Florida 32401

Attention: Mr. Cliff Bonney
Code 733

Subject: Contract Technical Report No. 1 & 2

Gentlemen:

The results of the current status work performed on the referenced contract from initiation to November 4th are:

Contract negotiations were completed on 30 September 1976, the effective date of the contract. The efforts under the subject contract have been designated as EES Project A-1897 entitled: Radar Radac Interface. It will be executed within the Advanced Sensors Division of the Systems & Techniques Laboratory, with Mr. P. H. Ryan, Jr. acting as Project Director. Dr. G. W. Ewell and Mr. F. B. Dyer will provide general direction and consultation.

The Radar Sensor, which has been furnished by the government, has arrived and has been checked out as to completeness and it appears that all major items are available. The system has been uncrated and cosmetic work to remove marred paint and repaint have been completed. The system has been mounted on temporary stands and cabling is currently in progress. Testing of the indicators as far as possible without an operational radar has been completed and both indicators appear to be functioning. One trip has been taken to the Naval Coastal Systems Laboratory to initiate estimates of cable length and wave guide length and initial cabling will be done with sufficient allowance of error to fit in the initial areas. Request has been made that the government furnish cable and wave guide kits and spare parts kits if they are available from the inventory.

During the next monthly reporting period, cabling of the units in their temporary position will be completed. Then units will be powered up and analysis will begin to determine their operational status and rectify any problems that may arise.

Mr. Cliff Bonney
November 15, 1976
Page Two

The procurement of the log amps and various other items with long lead times has been initiated and all vendors indicate they will be able to provide long lead time items in a timely manner. The financial status to date is healthy and is expected to remain in good shape throughout the life cycle of the project. The project has expended $6,223.13 to date.

Sincerely,

Patrick H. Ryan, Jr.
Project Director

PHR:csf

FINAL TECHNICAL REPORT

on EES/GIT Project A-1897

RADAR/RADAC INTERFACE

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Atlanta, Georgia 30332

FINAL TECHNICAL REPORT

on EES/GIT Project A-1897

RADAR/RADAC INTERFACE

by

P. H. Ryan, Jr., J. C. Butterworth, J. C. Sturrock,
F. B. Dyer, and P. O. Mathiasmeier

prepared for

Department of the Navy
NAVAL COASTAL SYSTEMS LABORATORY
Panama City, Florida 32401

under

Contract N61339-75-C-0122-HR20

October 1977

Contract No. N61339-75-C-0122-HR20
Naval Coastal Systems Laboratory
Panama City, Florida 32401

A-1897 Final Technical Report
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

FINAL TECHNICAL REPORT

RADAR/RADAC INTERFACE

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ABSTRACT

This Final Technical Report summarizes efforts conducted under Contract N61339-75-C-0122-HR20. Technical efforts were directed to the modification of an AN/SPS-10 radar to provide improved resolution, data acquisition outputs, and transponder-aided craft identification. Methods of radar modification are discussed in detail as well as the operating procedures for the radar. Detailed schematics of the transponder and sampler are included. It was concluded that the RADAR/RADAC system will greatly improve range safety and will provide an excellent platform for computer aided tracking of range craft.

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LIST OF FIGURES

I. INTRODUCTION

This report summarizes the modification of an AN/SPS-10 radar and associated equipment to provide a high capability harbor and test range safety radar for use with the range and data control (RADAC) laboratory at the Naval Coastal Systems Laboratory (NCSL).

A. Background

The RADAC team for Special Craft Test and Evaluation has an ongoing program of instrumenting a test range at the Naval Coastal Systems Laboratory, Panama City, Florida.

In addition to existing real time tracking, environmental data, and complete data analysis systems, a need was seen for additional safety equipment for protection of test craft and other surface vehicles. A surplus AN/SPS-10 radar was removed from the USS Wilkinson and made available for the task.

The AN/SPS-10 radar was originally intended for use as a surface search radar aboard ships in the destroyer or larger class. Typical targets of interest were other large surface ships in and out of fleet formation. An improvement in range resolution was needed to adequately provide the protection required for test range safety. In addition to improved range resolution, the need for a wide dynamic range instrumentation type receiver was indicated.

To identify co-operative craft, two transponders were developed, fabricated, and tested, and special-purpose sampling equipment was designed, built, and tested. The purpose of this sampler is to pick out a return pulse from a specified azimuth and range, sample and hold this pulse long enough to convert from analog to digital (A/D), and then output a long analog signal equal in amplitude to the short radar pulse for recording purposes.

B. Summary of Tasks

In order to provide NCSL with a radar sensor to perform a test range surveillance function, provide information to RADAC, and acquire target signature data, an integrated program consisting of the following tasks was undertaken.

Task 1. Repair and Refurbishment of SPS-10 Radar

After receipt of the SPS-10, the radar was tested and problem areas were identified. The SPS-10 was then restored to its normal operating condition.

Task 2. Modification of SPS-10 for Acquisition of Range Data

Known reliability problems in the standard SPS-10 were resolved. This was followed by the incorporation of a logarithmic IF amplifier and suitable video distribution amplifiers into the system.

Task 3. Reduction of Pulse Length

The transmitted pulse length was reduced to approximately 100 nanoseconds to provide increased range resolution and mapping capabilities. By reducing the transmitter pulse length and increasing intermediate frequency bandwidth and dynamic range, the range resolution could be improved to approximately 50 feet.

Task 4. Incorporation of Range and Angle Tracking

Suitable cursors and data pickoffs were incorporated to provide a tracking capability in range and azimuth as well as a continuous readout of the position of the target being tracked throughout the test sequence.

Task 5. Installation and Performance Verification at NCSL

The equipment was installed at the NCSL. Proper operation was verified after installation as well as the equipment capability for carrying out a range surveillance function.

C. Report Organization

The following chapters detail the technical efforts directed to the modification of the AN/SPS-10 radar. Section II includes detailed discussions of both the modifications and the data acquisition capability of the RADAR/RADAC interface system. Block diagrams, schematics, and component location diagrams are also presented. Section III presents conclusions drawn from the project. The Appendices contain the antenna schematic, the telephone schematic and theory, and the listing of the TM-503 Internal Wiring for Samplers.

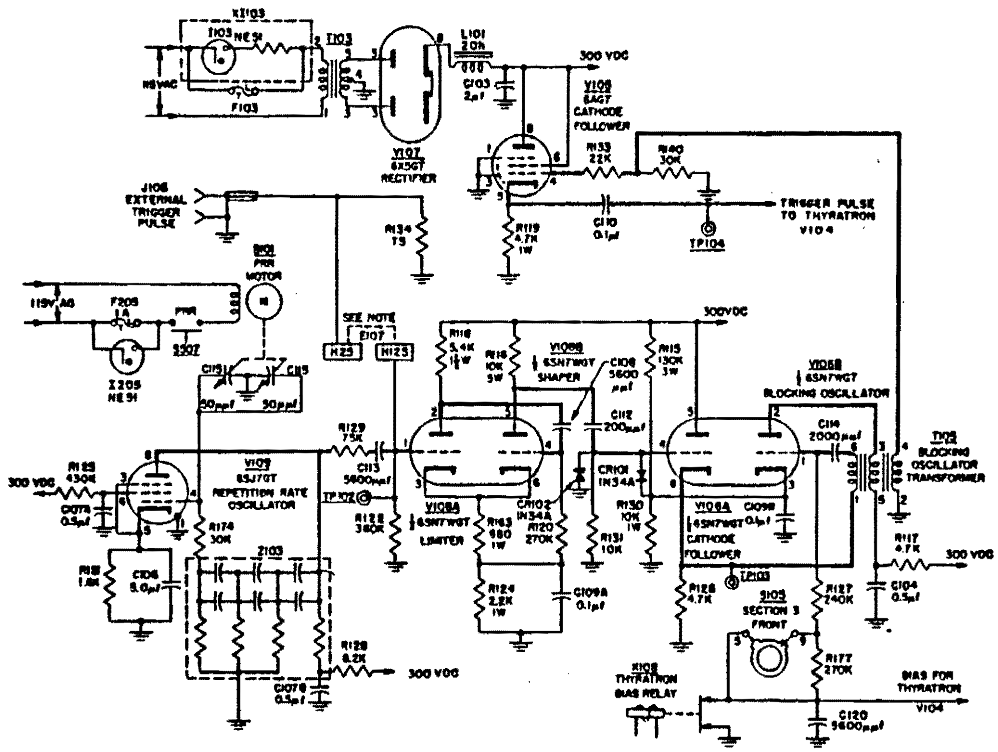
II. TECHNICAL APPROACH

A. Radar Modifications

1. Transmitter

In order to meet new radiation requirements, it was necessary to modify both the pulse repetition rate and the available pulse widths. This made basic modifications to the design of the modulator circuitry necessary. The phase-shift network Z102, shown in Figure 1, is utilized by the master oscillator V109. To meet the first requirement, the phase-shifting network was replaced with a new unit resulting in a basic pulse rate of 1200 pulses per second. Since this high rate could only be used in the narrowest pulse mode without exceeding the duty cycle of the transmitter, it was necessary to reduce it when the radar was operating in the two wider modes. The modulator was originally designed to half the pulse rate in the "beacon" mode by adding a resistor in series with the grid resistor of the blocking oscillator V106B, thus changing its time constant. This required that one section of switch S105 be modified and that the values of two resistors R127 and R177 in the blocking oscillator circuit be changed to give the proper frequency division at the new pulse rate. These modifications resulted in pulse repetition rates of 1200 and 600 pulses per second.

The new pulse width requirements were met by installing an oil-filled capacitor to obtain the 0.1 microsecond pulse width and by utilizing two sections of the original pulse forming network to obtain the 0.3 and 1.0 microsecond pulse widths. This required a new switching sequence which was accomplished by modifying the pulse width switch S106 and its associated circuitry, as shown in Figure 2. Switch S105 was also modified (see Figure 3) to meet the requirements of the magnetron filament program in the new circuitry as was the remote pulse width switch S505. The magnetron undercurrent sensing circuits and current metering circuits were reprogrammed so that the radar would operate correctly in all pulse width modes and would give the operator correct current indications.



Modulator, Radar MD-176A/SPS-10, Trigger Pulse Generator, Simplified Schematic Diagram

Figure 1. Phase-Shift Network.

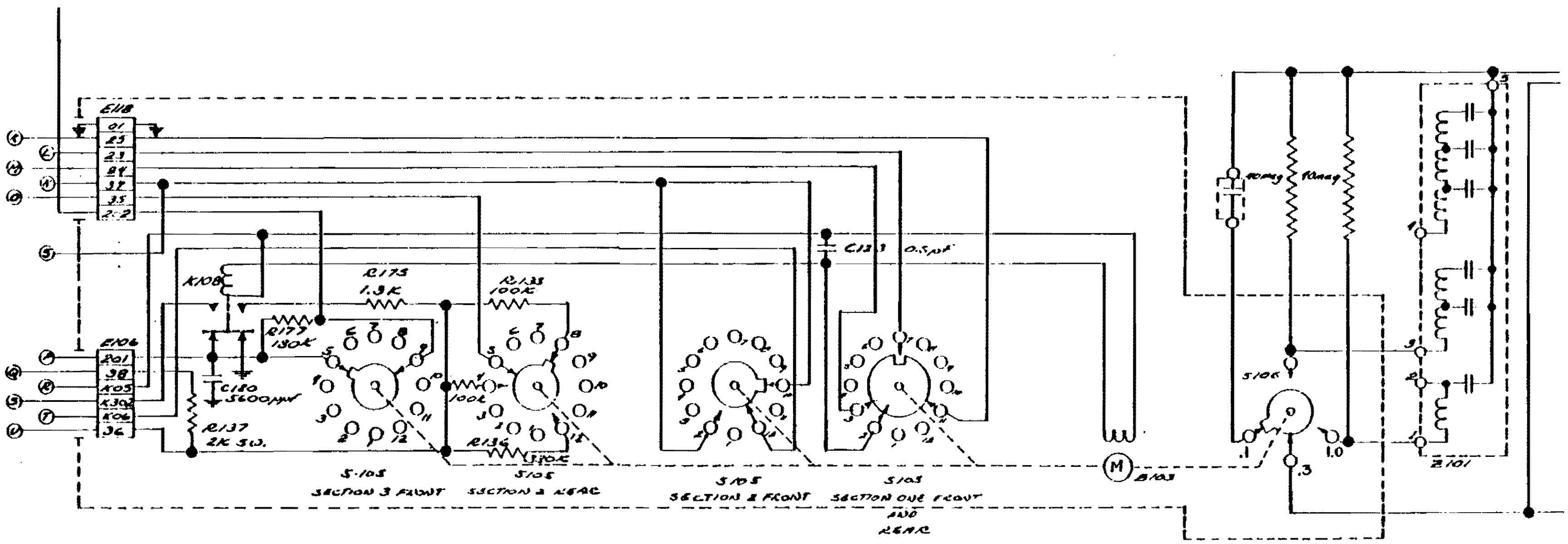


Figure 2. Pulse Width Switch S106.

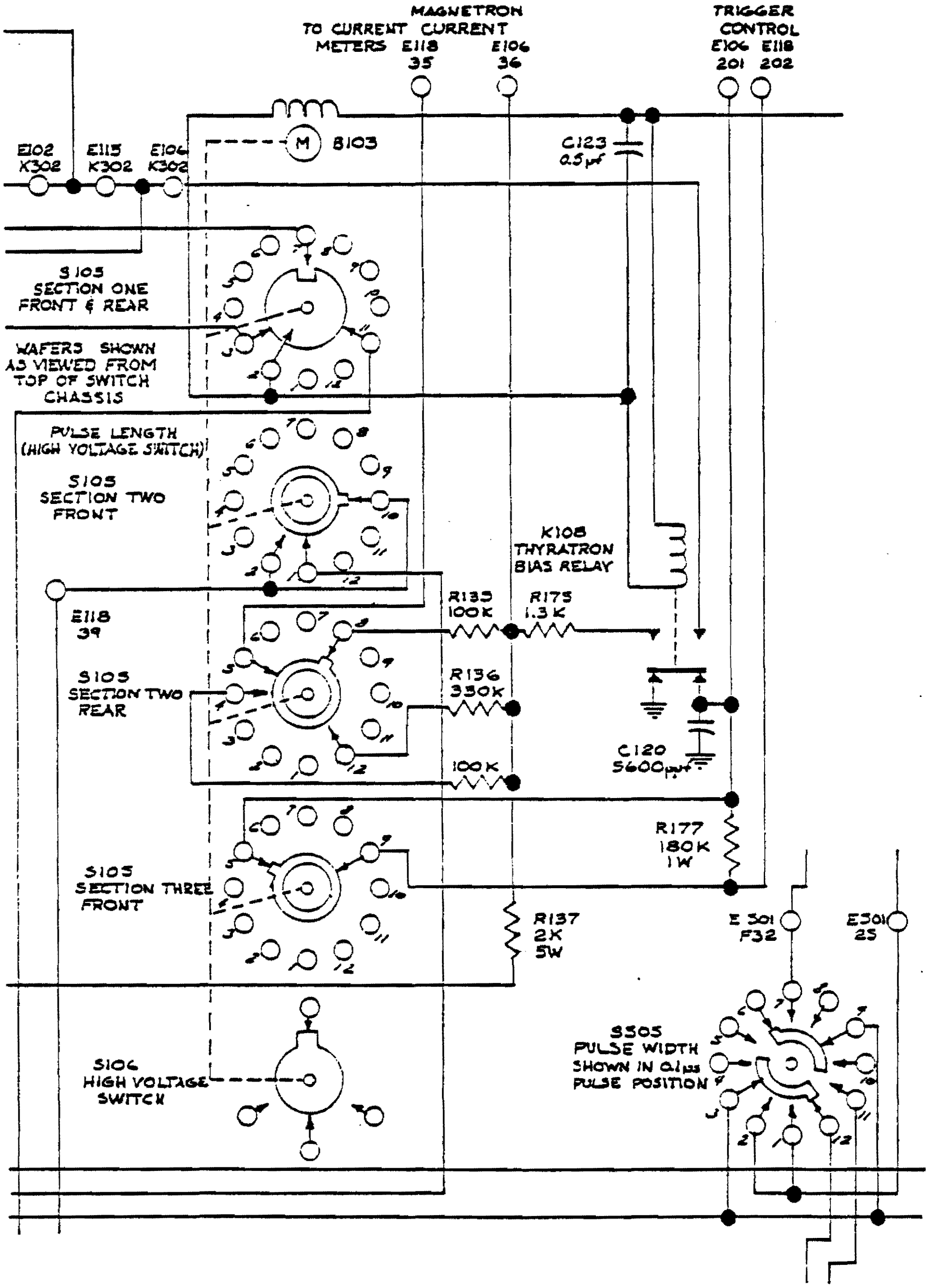


Figure 3. Pulse Width Switch S105.

In the event the magnetron must be replaced or retuned, or the receiver retuned, the receiver should be tuned to the transponders and the magnetron should be tuned to the receiver, as the transponders have the greatest long-term stability.

2. Receiver

To operate some of the peripheral equipment associated with the system, it was necessary to install a logarithmic intermediate frequency amplifier in addition to the original linear unit. As shown in Figure 4, a solid state unit with detector and video amplifier was installed inside the receiver/transmitter cabinet with its input obtained from the cathode terminal of the third linear IF amplifier stage V303. The detected video output of the logarithmic IF amplifier was then fed to a low-impedance output line driver mounted in a case outboard of the receiver/transmitter. This is illustrated in Figure 5. In addition, the detected output of the linear IF channel was fed to an identical video line driver located in the same unit. The line driver unit provides two identical isolated outputs for each input channel. These outputs are low impedance (50 ohms) and are suitable for driving long lengths of coaxial transmission cable to remote indicators. In addition, a power supply located in the same package provides the necessary operating voltages for the line drivers and logarithmic IF amplifier. Located in the unit is a resistive voltage divider network fed by a high voltage trigger pulse from the modulator and from which two triggers are available. One trigger output is sent to the remote indicators while the other is available for test purposes.

3. Indicators

To provide the sampler system with a voltage source that varies in proportion to the bearing of the antenna at any point, a precision potentiometer is mounted in one of the remote indicators (SPA-25's) with its shaft mechanically coupled to that of the bearing resolver motor. The output of this potentiometer is fed to coaxial connectors on the side of the indicator where it is available for use in the azimuth timing circuits of the sampler.

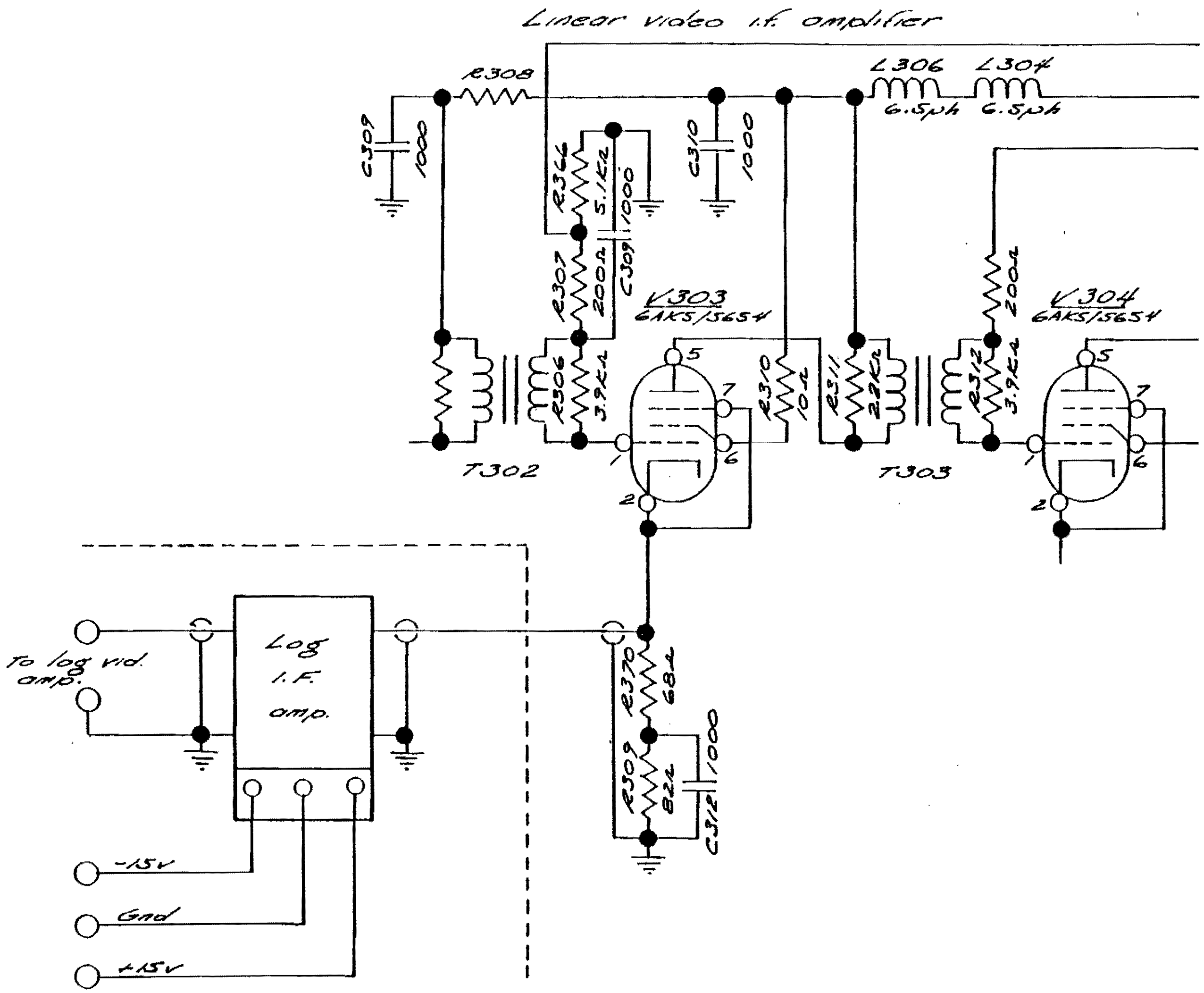


Figure 4. Logarithmic IF Amplifier Installation.

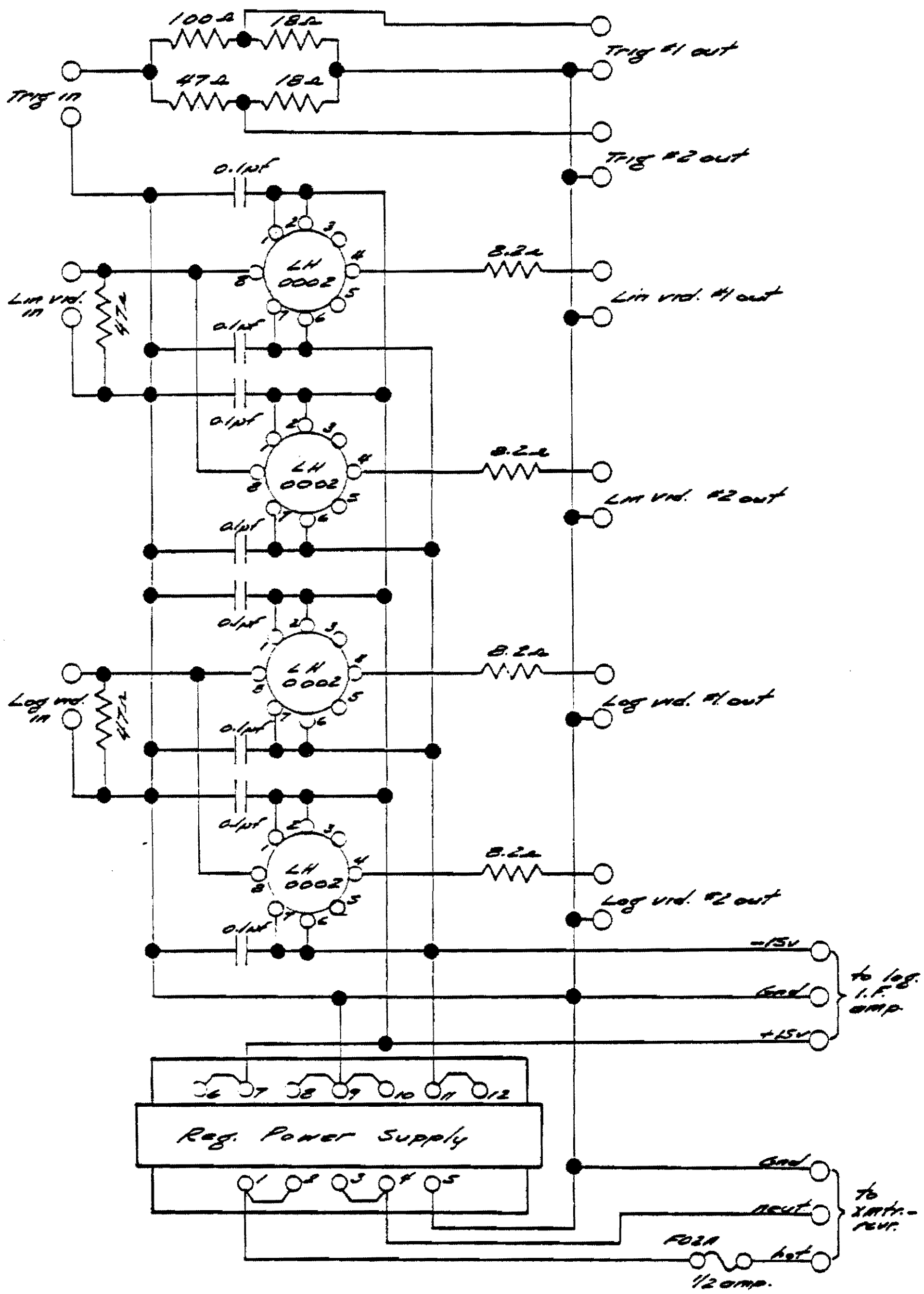


Figure 5. Line Driver.

B. Data Acquisition Capability

1. Transponder

The transponder is a device used to enhance the radar detectability of a small RCS target. Targets such as outboard motorboats (14-18 foot class), light aircraft, and small helicopters, might be classed as targets which could benefit from transponder enhancement. The enhanced radar echo from the transponder should appear as a strong target at the same azimuth, and approximately 70 meters beyond the actual location of the target vehicle.

a. Operation

The transponders furnished with the modified AN/SPS-10 radar are designed for use with any radar operating at 5.71 GHz. The transponder is operated simply by connecting the power cord to an ordinary 12 volt storage battery system, such as found in an outboard motor boat or an automobile. The power cord is connected with the black lead to the negative terminal and the white lead to positive terminal. The switch on the end of the transponder is then placed in the ON position. NOTE: The transponder should NOT be operated without the antenna in position and clear of any metal obstruction. Two ON positions are provided. In the ON ALERT position, the transponder sounds an alert alarm each time it is interrogated, and in the ON position, the alert signaler is disabled.

b. Circuit Description

The transponder system consists of a broadly tuned video receiver with a threshold sensitivity of approximately -40 dBm, a pulse to generate a 0.5 μ sec pulse with appropriate amplifiers to operate a solid state Gunn diode oscillator tuned to 5.71 GHz, with an output power of 10-20 watts peak. Appropriate power supplies are provided for conversion of the 12 volt battery source to those voltages needed for the system.

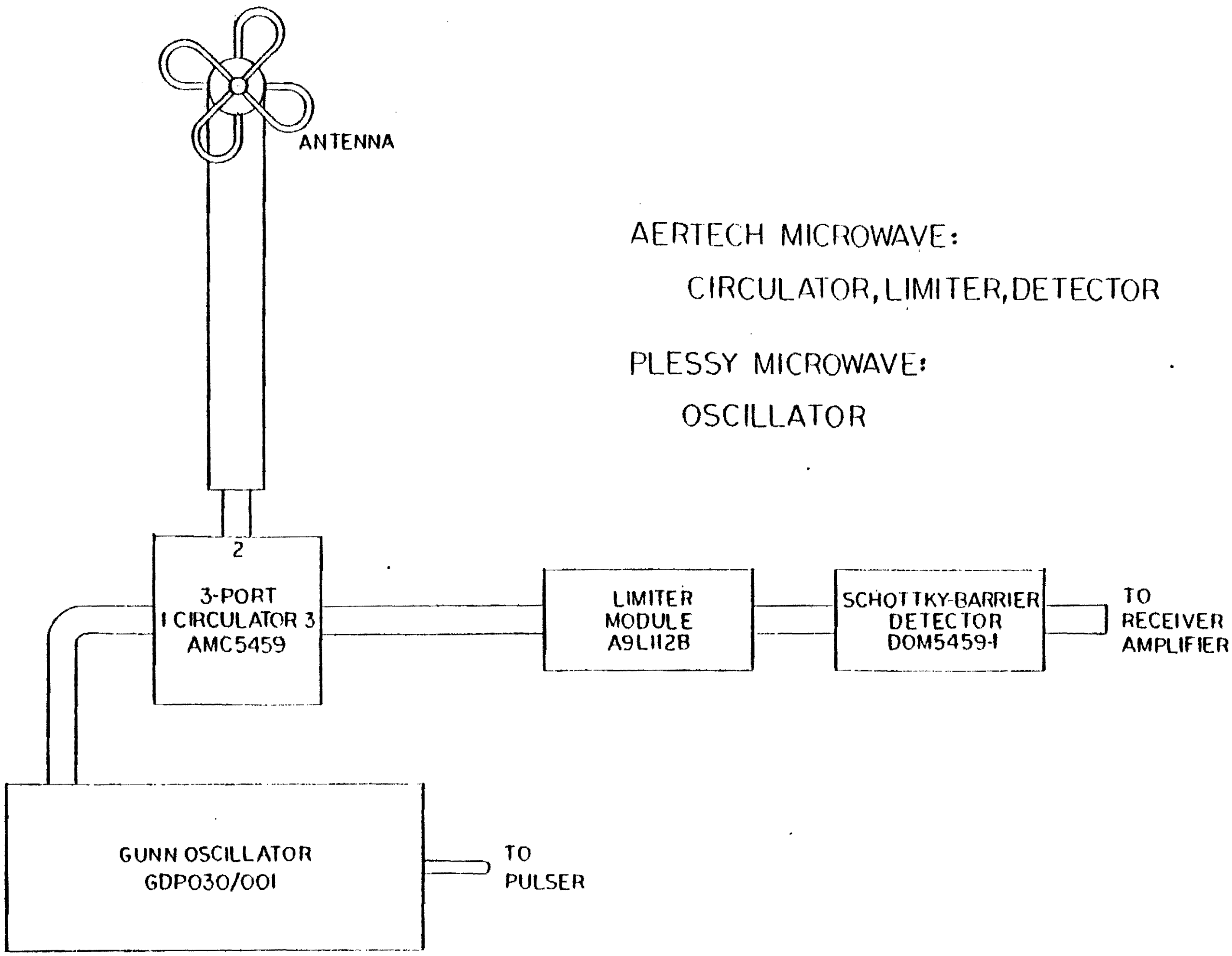


Figure 6. RF Portion of the Transponder.

The RF portion of the transponder consists of a horizontally polarized omni-directional transmitting and receiving antenna, a three port circulator, a solid state crystal limiter, a Schottky-Barrier replaceable crystal detector, and a pulsed Gunn diode oscillator, shown pictorally in Figure 6.

The circuit portion of the transponder is contained on three printed circuit cards: (1) Receiver, (2) Pulser, and (3) Power Supply.

The receiver board contains a five stage R-C coupled transistor amplifier with adjustable threshold and TTL compatible line driver (see Figures 7 and 7a). Diode limiting networks were used throughout to enable the amplifier to handle a wide dynamic range of inputs from -40 dBm to the limited input from its own 20 watt RF pulse source. The only adjustment was in the receiver threshold which is set to give a suitably low false alarm rate to the transponder (less than 10 per minute). An excessively high threshold setting will naturally affect the transponder's minimum detectable signal and range capability.

The pulse board contains timing circuits and driver amplifiers for the pulse oscillator as shown in Figures 8 and 8a. An inverter is followed by a Schmitt trigger coincidence gate which drives a one-shot multivibrator thus generating the basic 0.5 μ sec pulse. The external R-C time constant is selected to produce the necessary pulse when measuring the RF output. The first one-shot then triggers another one shot which generates a pulse used to limit the transponder interrogation rate. This pulse, approximately 700 μ sec long, is then applied to the coincidence gate at the input. Only after the conclusion of the lockout pulse will the pulse produce the next 0.5 μ sec pulse. This lockout circuit is provided to limit the maximum pulse rate of the Gunn diode oscillator to within the rated specifications. The lockout circuit also provides a trigger to the interrogation

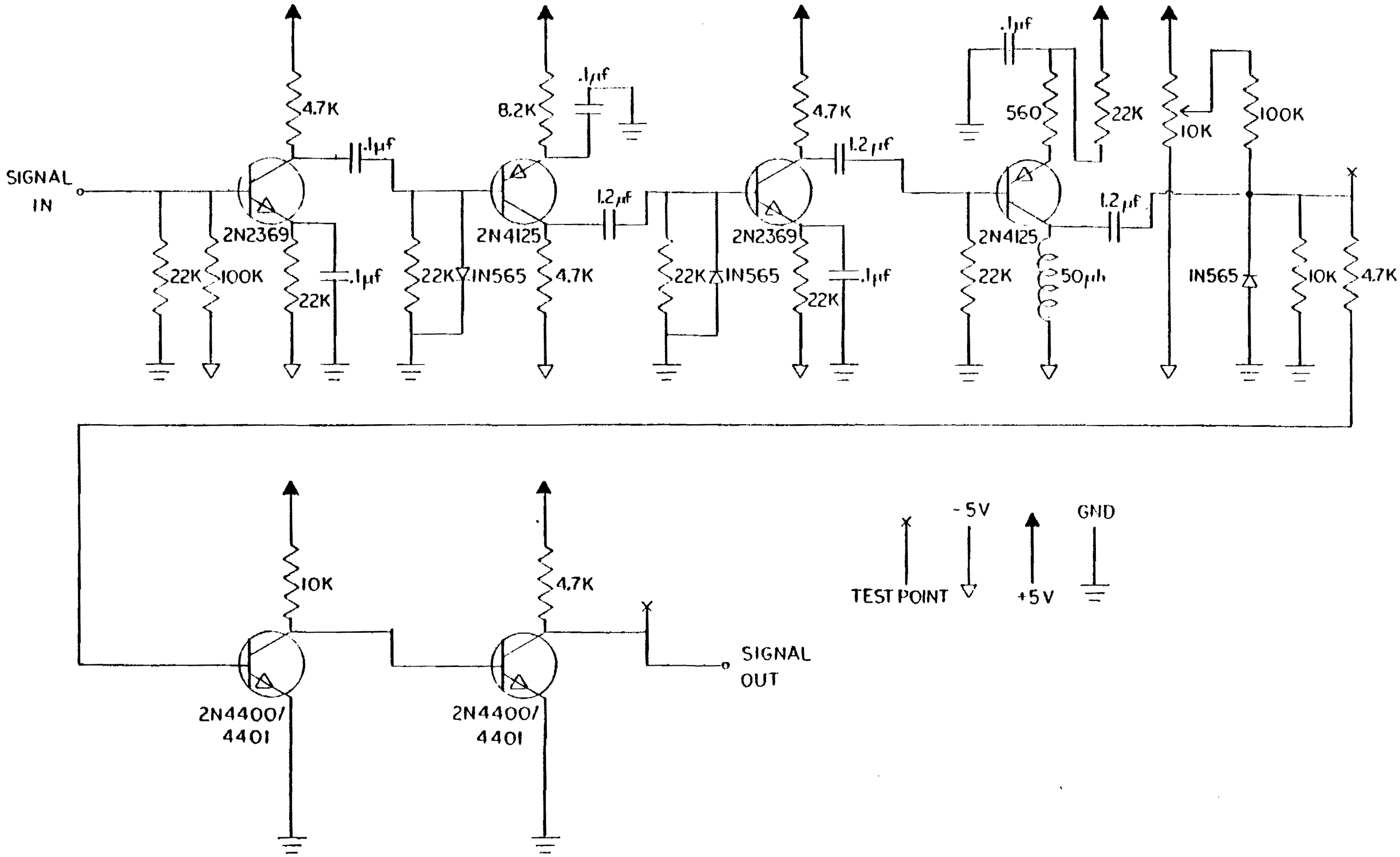


Figure 7. Transponder Receiver Schematic

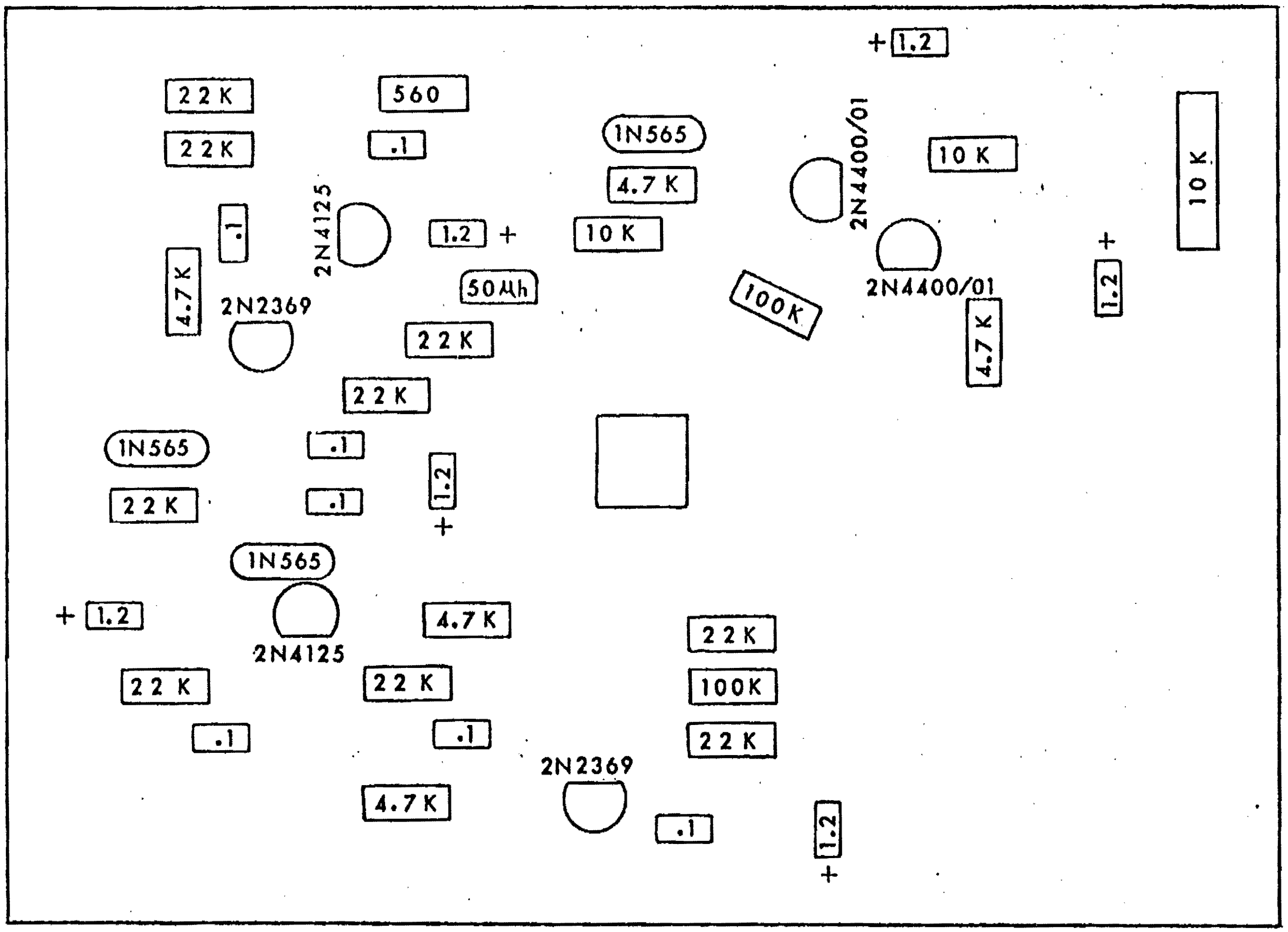


Figure 7a. Transponder Receiver Printed Circuit Card Component Placement.

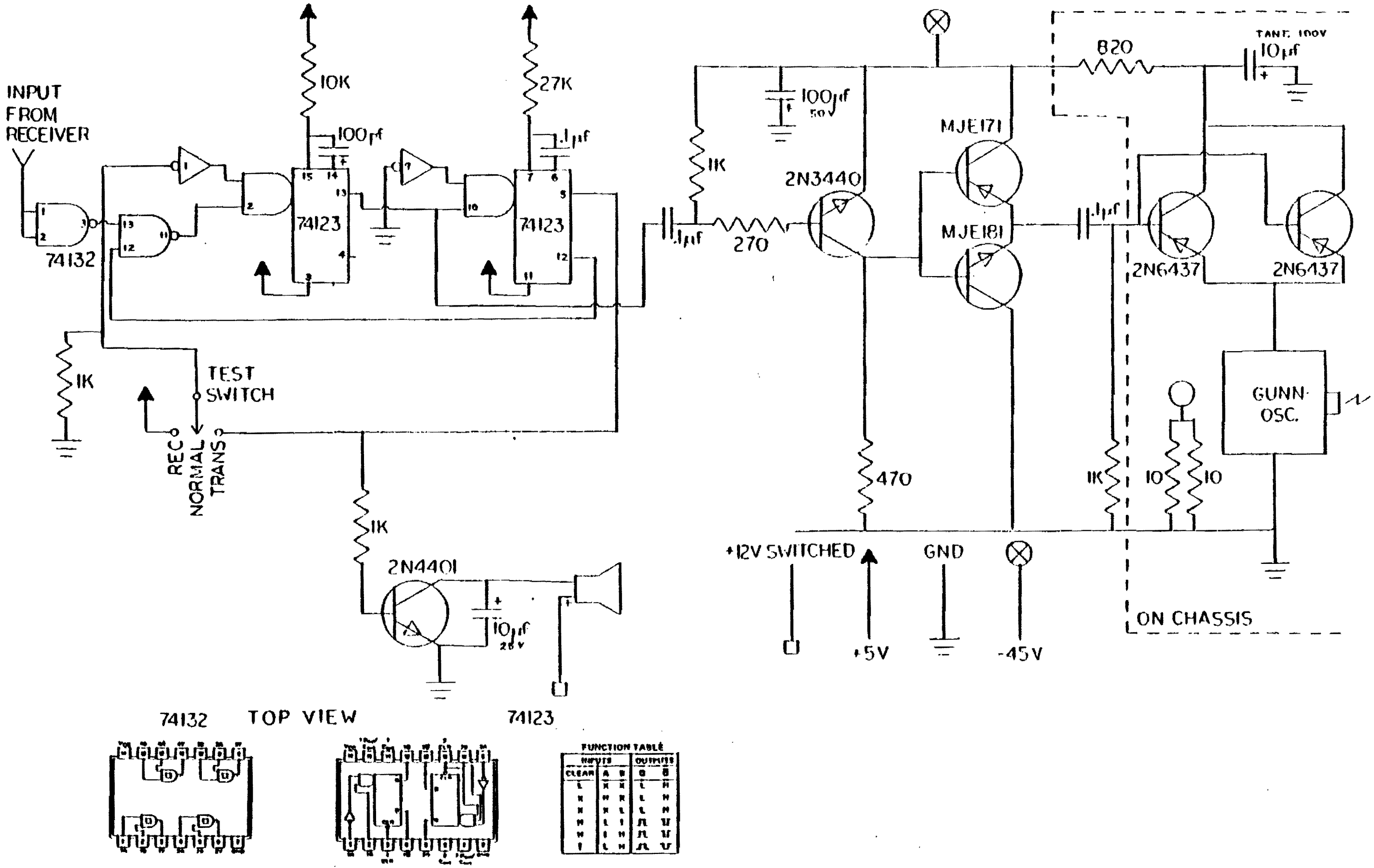


Figure 8. Transponder Pulser Schematic.

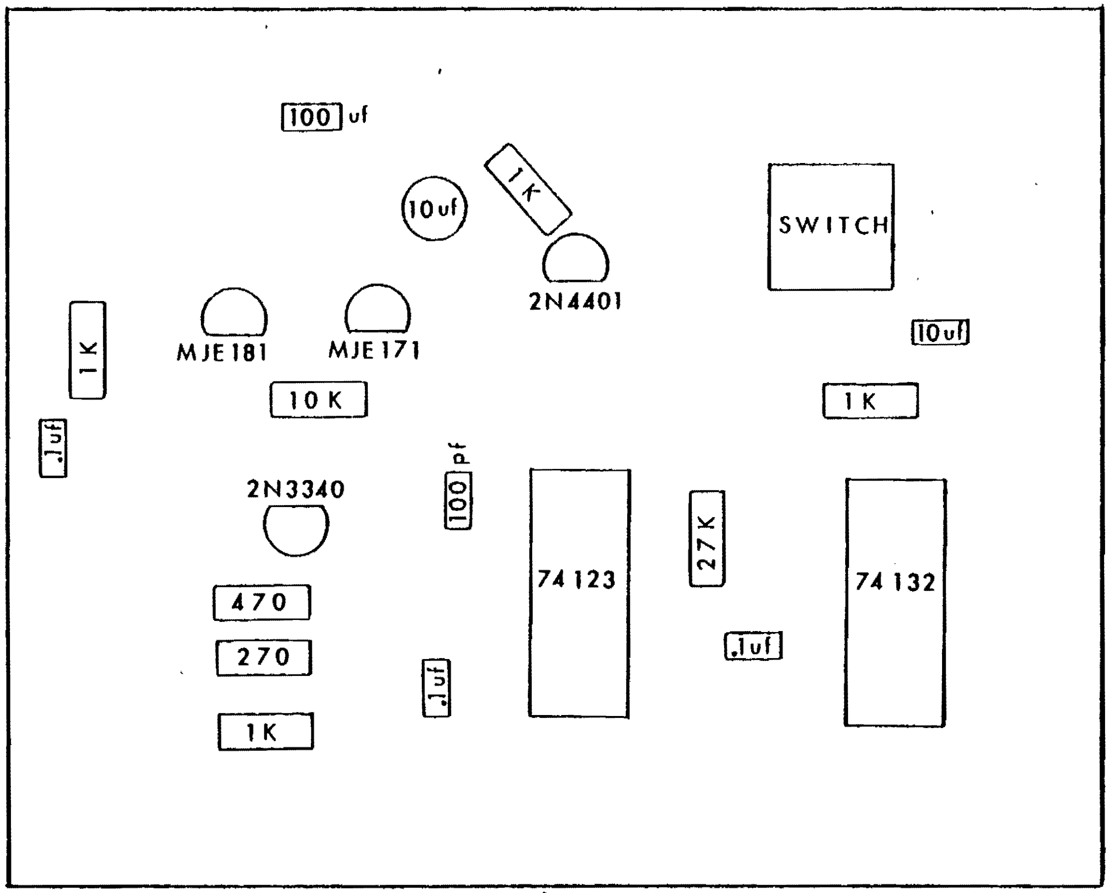


Figure 8a. Transponder Pulser Printed Circuit Card Component Placement.

ALERT alarm. This alarm will provide, when energized, a 1/4 second audible tone when the transponder has transmitted one pulse. The total duration of the ALERT signal will directly indicate the length of an interrogating signal which exceeds the receiver threshold.

A transistor voltage amplifier is coupled to the output of the 0.5μ sec one shot. This is followed by a complementary pair current amplifier which drives the emitter follower pair current amplifier mounted on the main chassis. This amplifier chain provides the necessary 35-39 volt 20 amp negative pulse to operate the Gunn diode oscillator. A test switch is provided for servicing the transponder. When the three position switch is in the center, it is in normal operation. When in the RCV position, the 0.5 sec one-shot is disabled, providing safety for the Gunn diode. When the test switch is in TX position, an interrogating input signal is not needed to operate the pulser. For TX test, the switch is placed in TX position, then the main power is switched ON. This will start the two one-shot circuits in a continuous oscillation loop, producing a 0.5 μsec pulse every 700-900 sec. A dummy load resistor (5 Ω) is also provided for use while servicing the pulser section. The lead to the Gunn diode oscillator is unsoldered from the oscillator post and soldered to a dummy load. Utmost precautions must be observed during work which will affect the pulse width, rate, and amplitude applied to the Gunn diode oscillator. Accidental overload and burnout can easily occur. Maximum limits are -39 volts, 0.5μ sec pulse, and .5% duty cycle. Application of DC voltage will cause burnout.

The power supply circuit board (Figure 9 and 9a) consists of a high voltage negative supply and two 5 volt low voltage supplies along with input over voltages and reverse polarity protection. The input to the transponder is first protected by a 3/10 amp fuse (normal input power 11 - 14.5 volt DC at 1/4 amp).

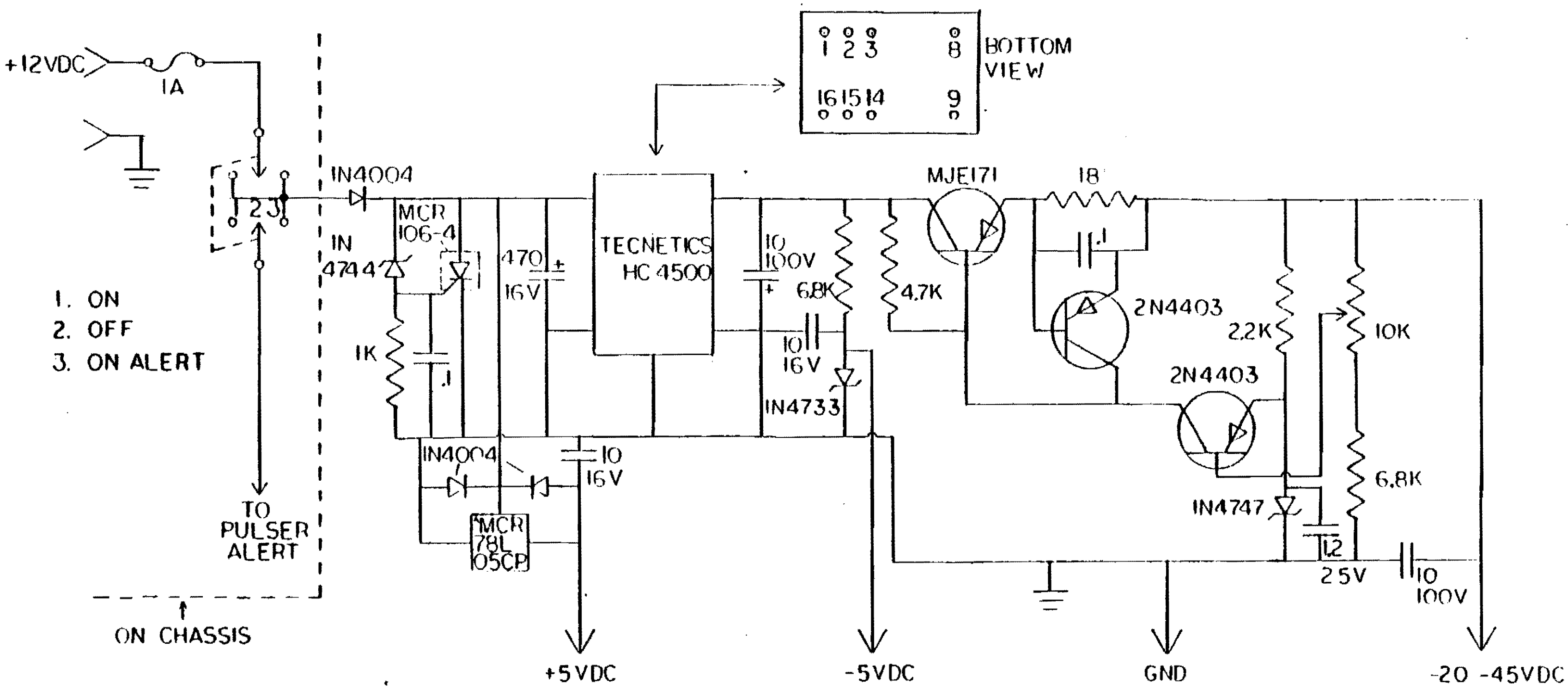


Figure 9. Transponder Power Supply Schematic.

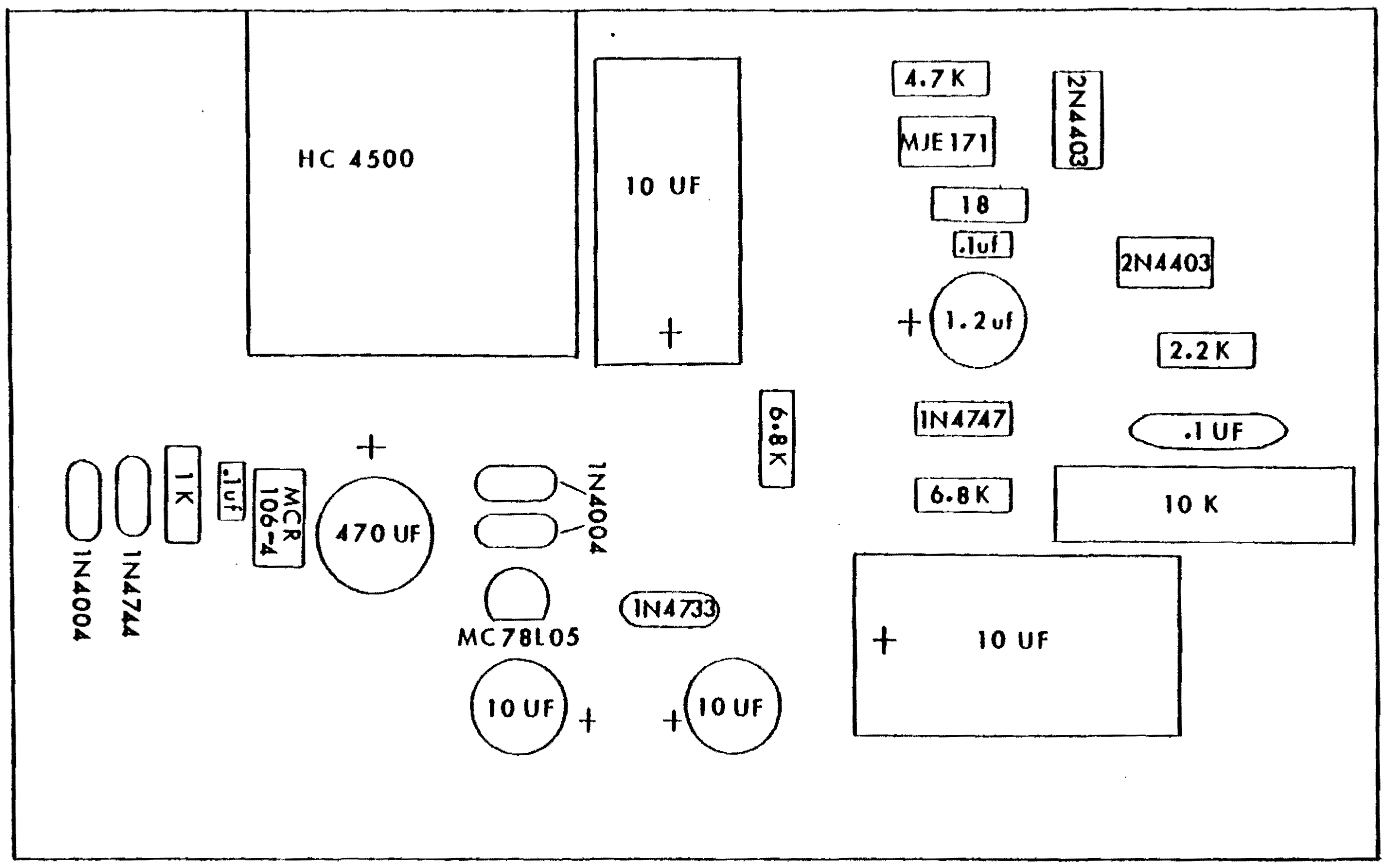


Figure 9a. Transponder Power Supply Printed Circuit Card Component Placement.

In the event that the input voltage exceeds 15 VDC (faulty battery or charging system), a SCR crowbar is switched across the DC input line causing the fuse to blow. After correcting the supply voltage and replacing the fuse, the system should operate normally. The negative high voltage is provided by a DC to DC converter rated at 50 volts, 60 MA, followed by an adjustable voltage solid state current limited regulator which provides a -20 to -45 volts at 40 MA voltage to the Gunn diode and amplifier. This supply voltage is adjusted to set the proper operating conditions for the Gunn diode oscillator. The negative 5 VDC is supplied from a zener diode regulator from the DC to DC converter. The positive 5 VDC is supplied from a 7805 three terminal solid state voltage regulator connected to the 12 VDC input supply. The negative low voltage supply delivers less than 10 MA average current and the positive low voltage supply delivers less than 100 MA current.

2. <u>Sampler</u>

a. Sampler Operation

Operation of the sampler units is relatively straightforward. The only operator controls are two front panel adjustment (range and azimuth) and three mode switches (clutter on-off, normal-expanded PPI, and normal-stare mode). The range potentiometer selects the target range and is marked on the PPI by a set of rings that are adjusted by the range control to bracket the target. The azimuth position of the sample is marked on the PPI by an azimuth strobe that can be adjusted by the azimuth control to coincide with the target. The clutter sample is taken coincidentally with the clutter marker and on the azimuth strobe. The clutter marker can be turned on or off by the front panel switch and adjusted by a front panel trim pot. The PPI can be used in an expanded mode to assist in target acquisition. If the normal-expanded switch is in the expand mode, the PPI will display radar returns that start one mile before the target sample is taken (adjusted by the first range trim pot). The mode of the sampler system can be changed to either normal mode or stare mode in which there is no azimuth gating by the front panel switch. This allows the radar rotation to be stopped and pointed at a target or alternately to be used in a test mode that takes samples once each Pulse Repetition Interval (PRIL).

b. Block Diagram Description

Signals from the Receiver-Transmitter Modulator (RTM) of the SPS-10 arrive in the timing unit at the common-mode conditioning circuitry. From these, the trigger, log, and linear video go to distribution buffers and out to the PPI, samplers, and timing units. The azimuth circuit provides a one PRI gate at the selected azimuth location, or if the normal-stare switch is in the stare mode, the gate is active at each PRI. The range circuit delays the sample trigger for the appropriate delay as fixed by the range pot. The clutter sample is taken previous to the target sample and is adjusted by the clutter trim pot. The marker generator circuit makes the PPI markers for range, clutter, and azimuth strobe. The refresh circuit resets the sampler after each sample is taken. The sampler block diagram is depicted in Figures 10 and 11.

The sampler operates as a very fast track and hold device. An input buffer lowers the impedance to the sample switches and capacitor. When a trigger arrives, the sample switch opens and the sample capacitor is referenced to ground. Following amplifiers condition the signal and the A/D converter digitizes it. A delay circuit allows the following amplifiers to settle before the A/D converts. A data-ready flag is raised at the completion of conversion. This flag is fed back from the timer unit reseting the input switch, and delay circuitry. The A/D

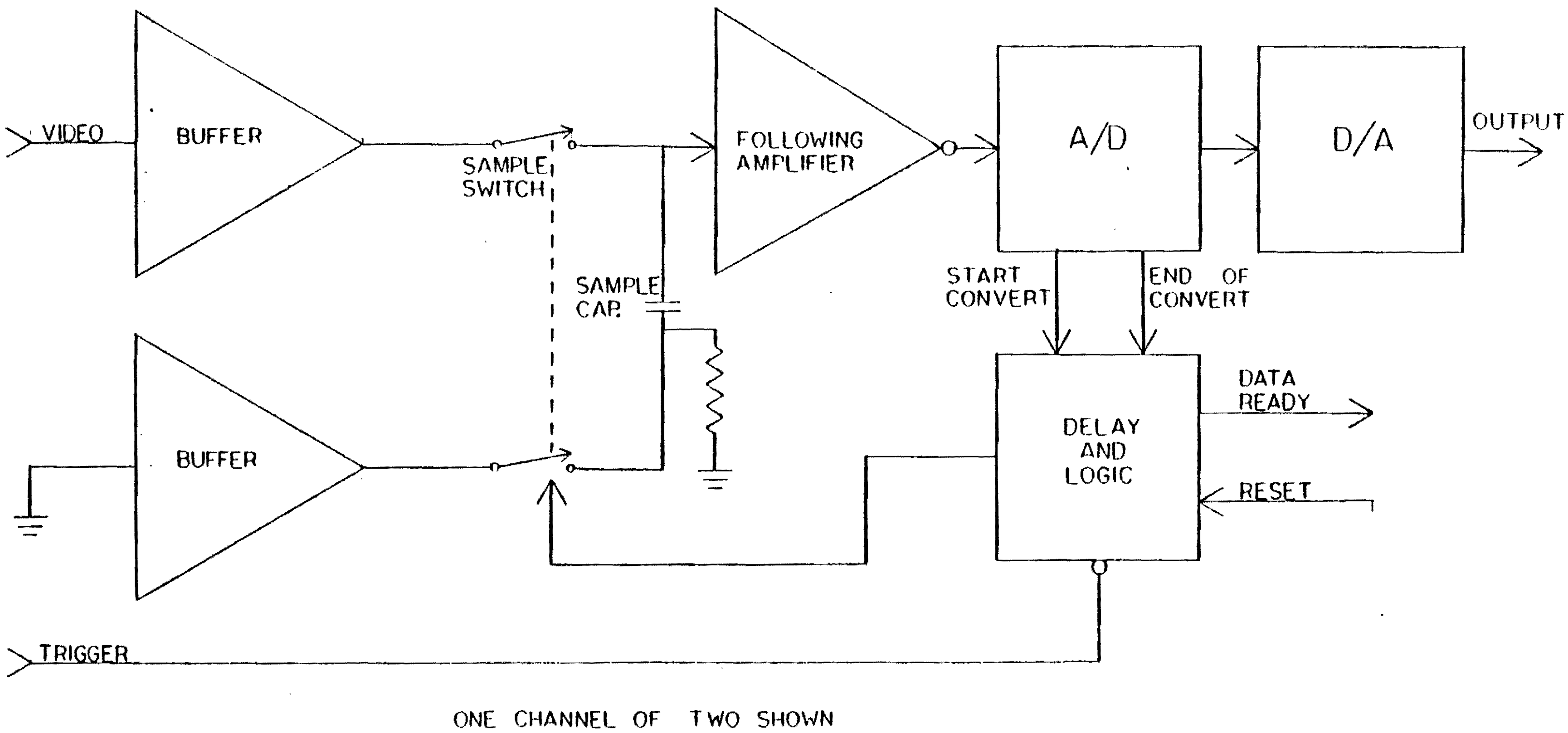


Figure 10. Sampler Block Diagram.

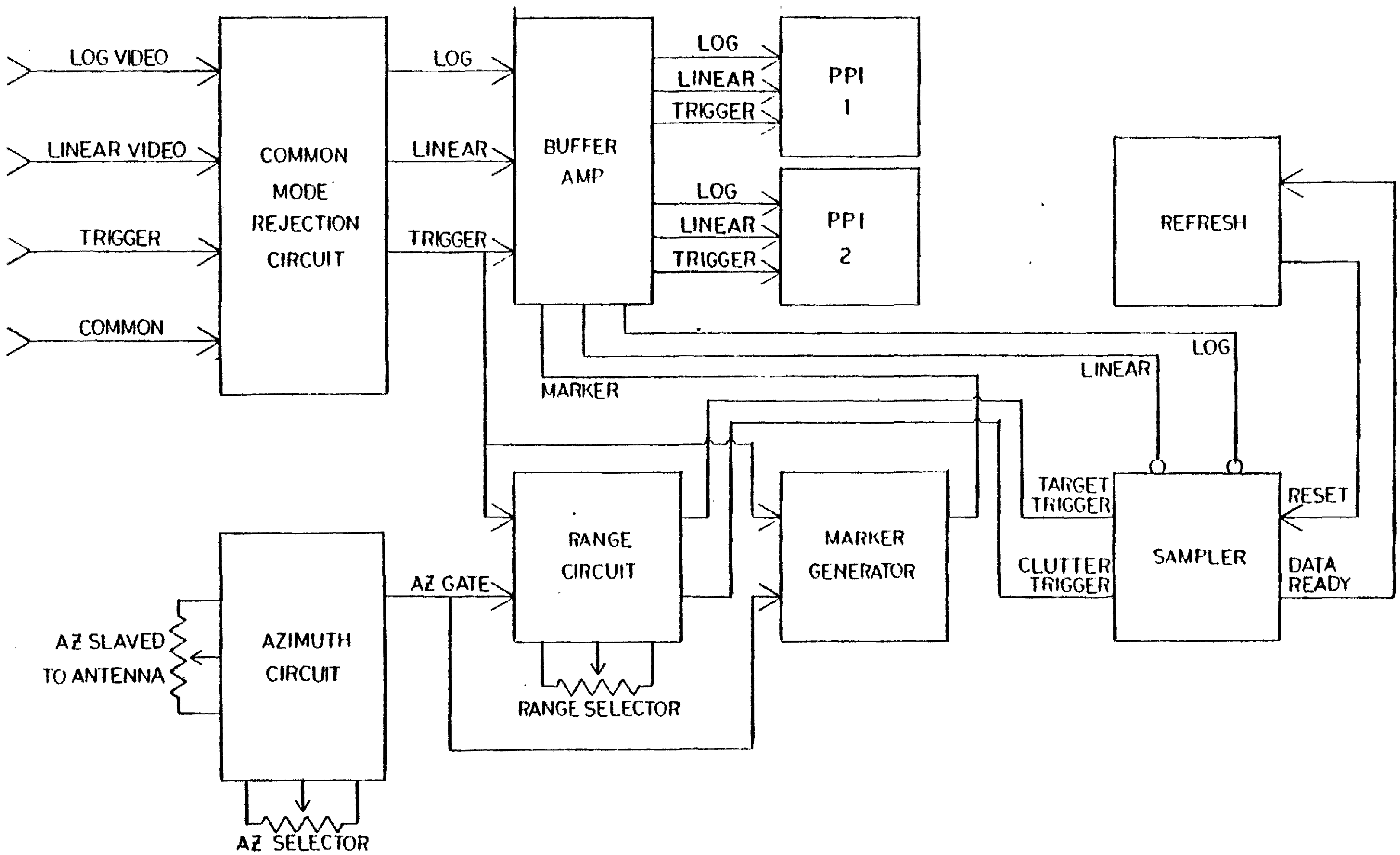
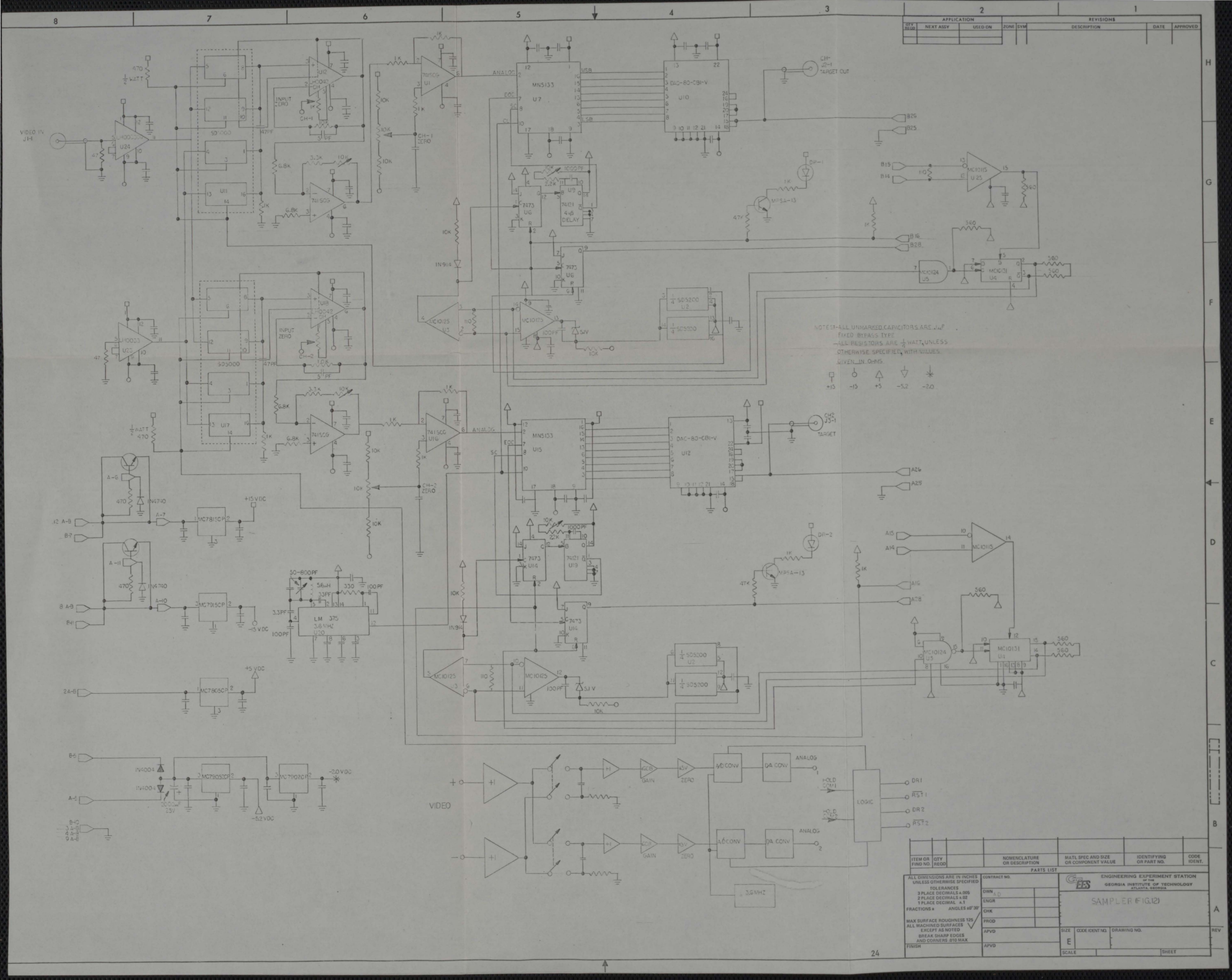


Figure 11. Timebase Block Diagram.



SAMPLER (FIG.12)

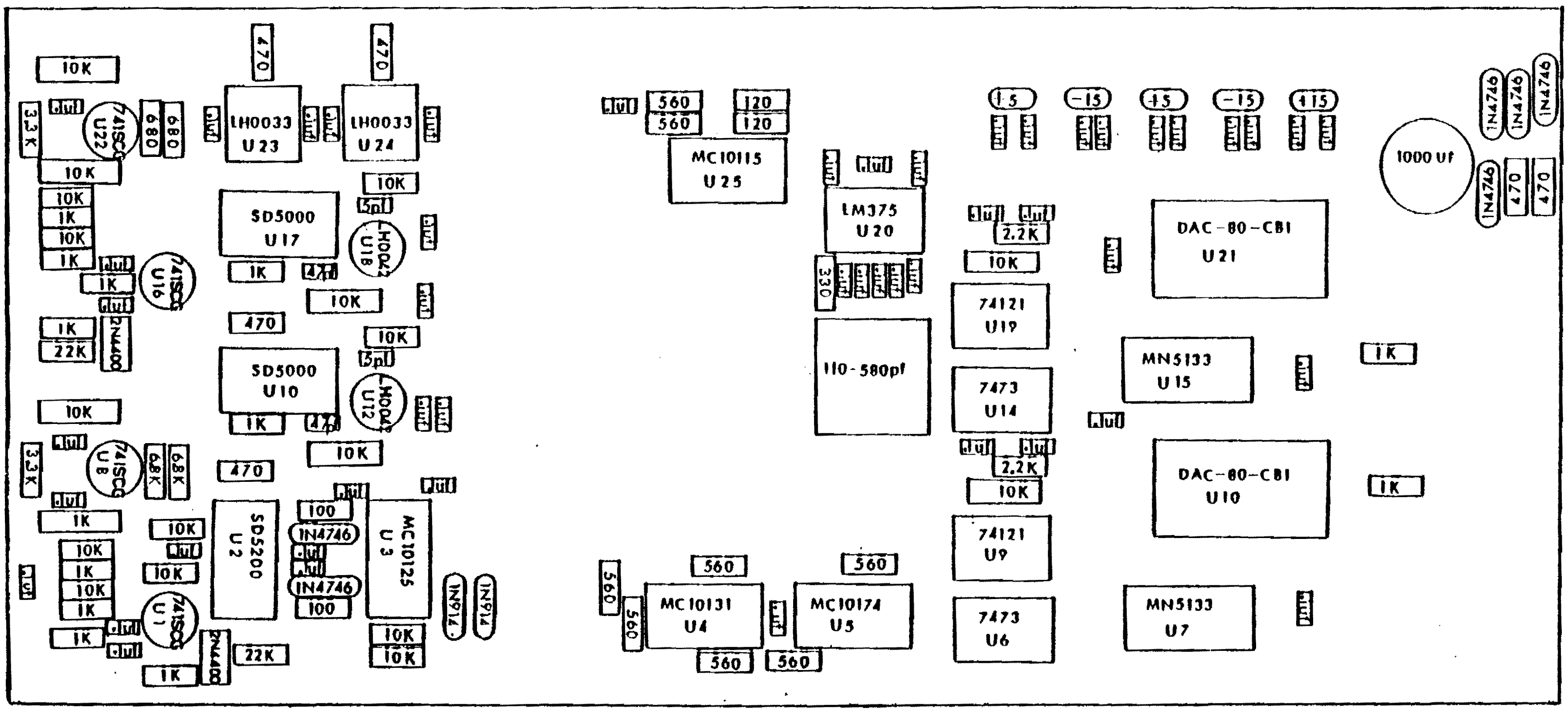
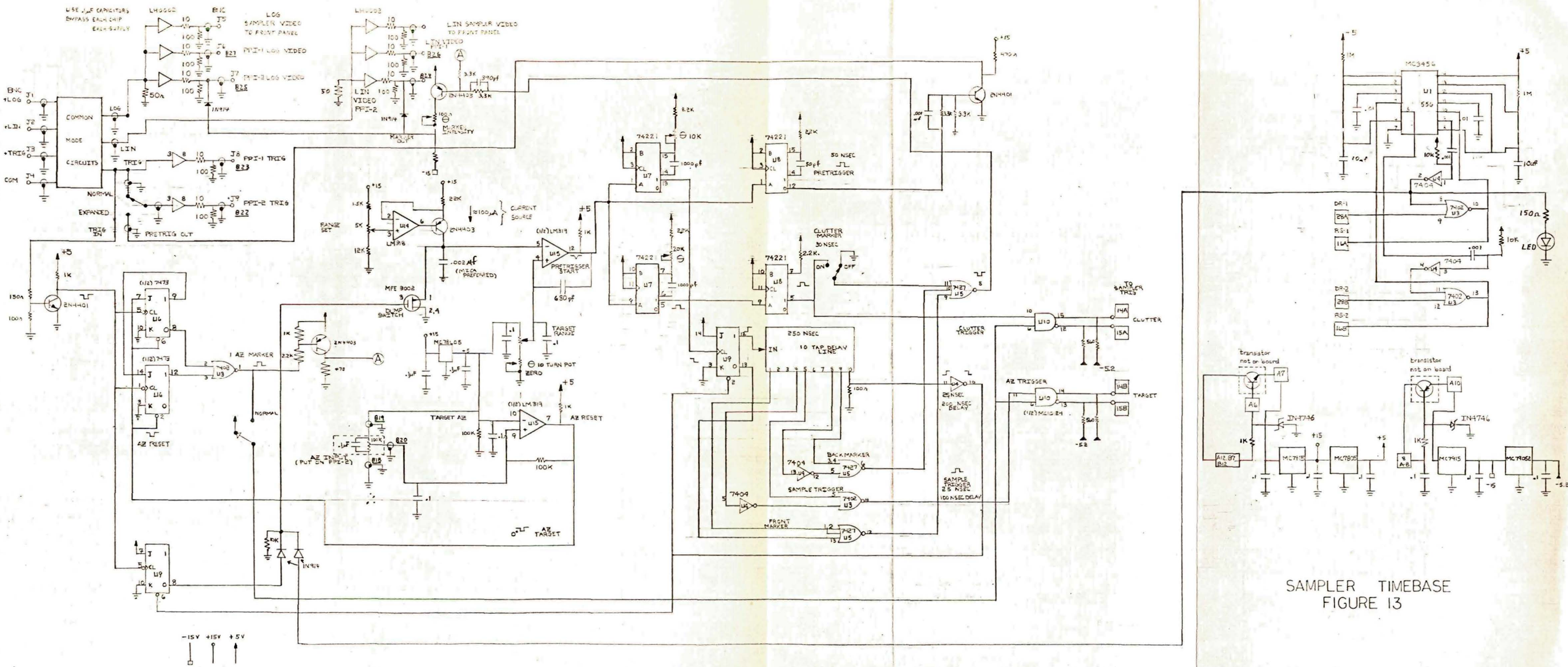


Figure 12a. Sampler Printed Circuit Card Component Placement.



SAMPLER TIMEBASE
FIGURE 13

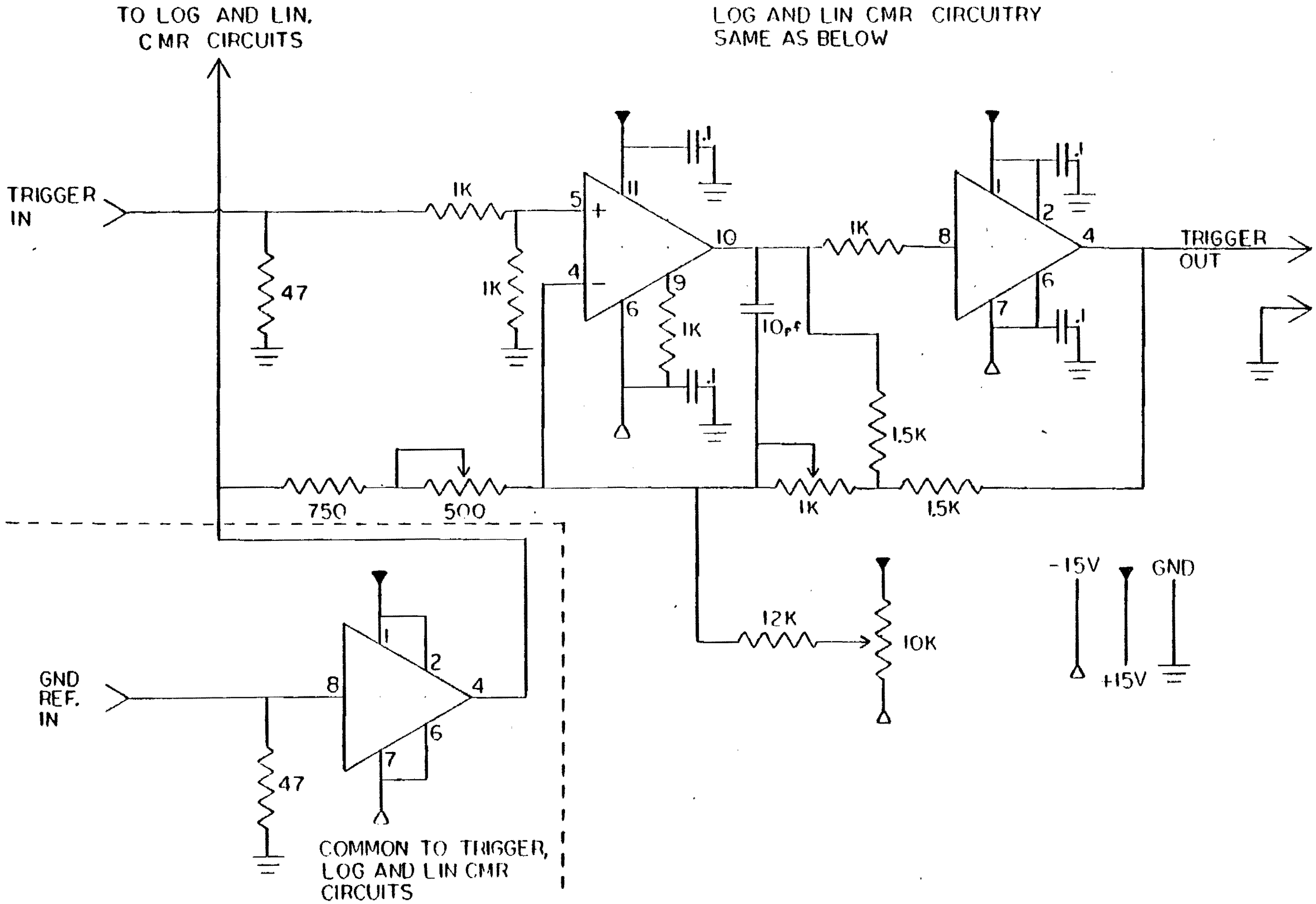


Figure 13a. Common Mode Rejection Schematic.

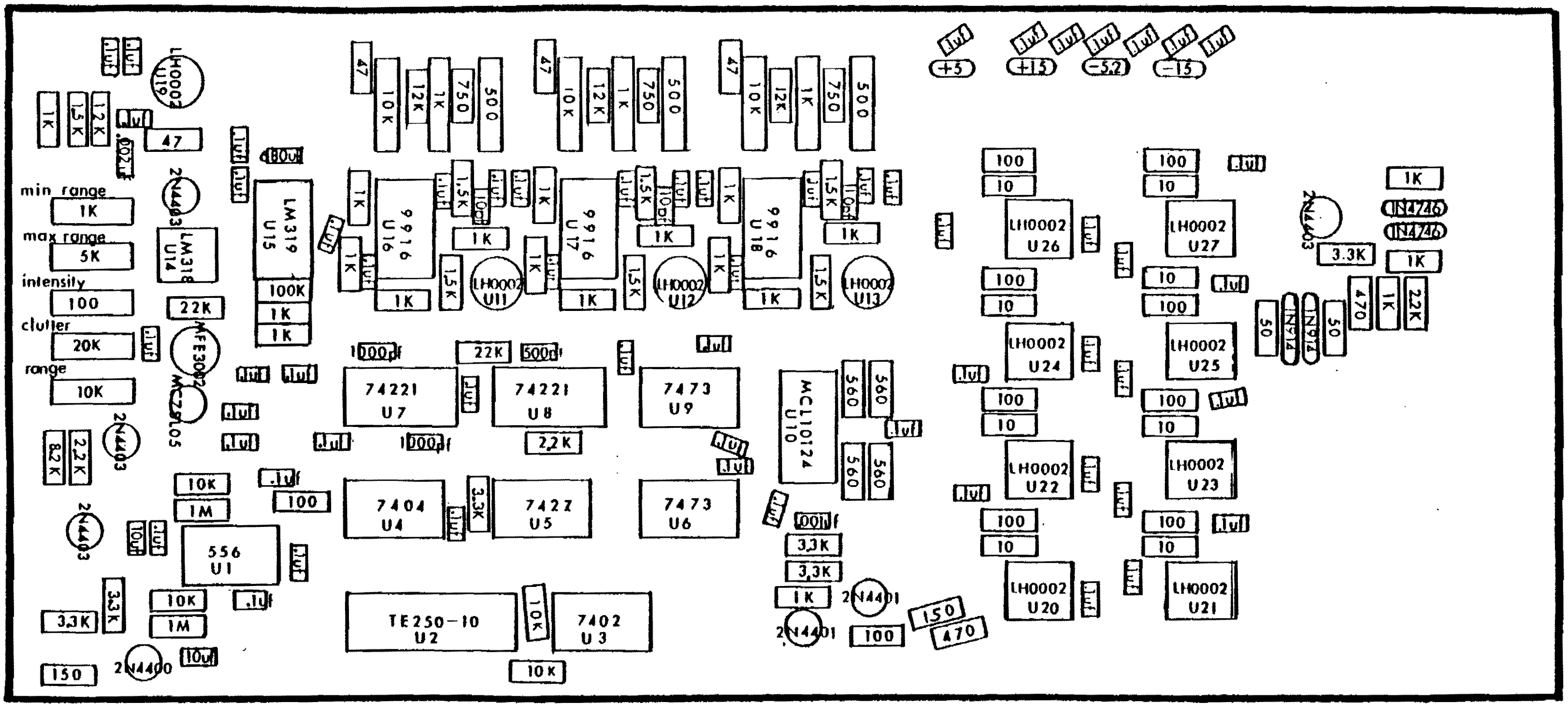


Figure 13b. Timebase Printed Circuit Component Placement.

holds its digital output data until a new sample command is given. The D/A regenerates an analog signal from the digital output. The target and clutter sampler are identical. Sampler diagrams are shown in Figures 12, 12a, 13, 13a, and 13b.

c. Hookup

Four cables come to the sampler from the RTM. These cables (log video, linear video, trigger, and common) are connected to the isolated BNC jacks on the timer unit. One front panel jumper is installed between the sampler video input and the timer log or linear video output. PPI-1 is hooked up to the rear of the sampler; linear video to jack A right; log video to jack A, and trigger to jack B right. PPI-2 is hooked up to the rear of the sampler; linear video to jack B, log video to jack A left, and trigger to jack B left. The azimuth input from the potentiometer is connnected to J1 of the back panel; pin 2 is ground, pin 4 is the wiper, and pin 6 is plus 5 volt reference, while pins 1, 3, and 5 are shield returns. Table I lists the sampler controls and their functions.

TABLE I

Sampler Controls

Front Panel Controls -- Timer

S-1	Clutter Marker On-Off
S-2	PPI Mode Normal-Expanded
S-3	RTM Mode Normal-Stare (searchlight)
Range	Nominally 1 to 11 miles
Azimuth	0 to 355^{o}

Front Panel Trim Pots

Timer

Range	Adjusts expanded range size and overall range minimum
Clutter	Adjusts position of clutter sample (before target sample)
Intensity	Adjusts intensity of markers
Max. Range	Calibrates maximum range on Range pot
Min. Range	Calibrates minimum range on Range pot

Sampler

Target gain	Adjusts gain of target sampler marker
Target offset	Adjusts zero offset of target sampler marker
Clutter Gain	Adjusts gain of clutter sample marker
Clutter Offset	Adjusts zero offset of clutter sample marker

Internal Trim Pots and Adjustments

Timer

Gain	Trigger, log, linear
Offset	Trigger, log, linear
Common Mode	trigger, log, linear

Sampler

Input zero	Sets sampler front end zero
Convert Time	Adjusts start of A/D conversion
A/D Oscillator	Sets frequency of A/D oscillator to 3.6 MHz

III. CONCLUSIONS

The installation of the modified radar and data acquisition equipment have the potential for significantly improved range safety while also providing additional tracking data. The current system, by use of the transponders, is able to both track appropriate sized craft and distinguish co-operative craft from non-co-operative, civilian craft. This allows the identification of undesired boats in the test area or the identification of severe weather conditions in or near the test area during operations. It also allows RADAC personnel to provide timely reports of potential hazards to craft having high velocity or limited manuverability. The reduction of pulse width to 100 nanoseconds has reduced the degradation due to sea clutter during rough sea conditions as well as enhancing the mapping capabilities and thereby extending the range of weather and sea conditions over which tests can be performed.

The capability to make radar signature measurements and record them for later analysis has been provided by the addition of a logarithmic IF amplifier, video distribution amplifiers, and a high-speed sampling unit. In addition, the cursors have tracking capability which allow them to be continuously recorded.

As the current data acquisition from the radar is manually controlled, a further upgrade to the system would be to provide for automatic tracking of the cursors. This capability would allow continuous computer calculation of velocity and probable collision vectors, thus improving the tracking and data acquisition ability of the RADAC facility. Perhaps a more significant upgrade would be the incorporation of a full digital processing front end to the radar, similar to that envisioned for the MIDAS test bed. This modification would allow the automatic processing of targets in the test area by the RADAC facility and would allow the full capabilities of the RADAC facility to be applied to the radar surveillance system.

APPENDICES

I. ANTENNA SCHEMATIC

II. TELEPHONE SCHEMATIC AND THEORY

III. TM-503 INTERNAL WIRING FOR SAMPLERS

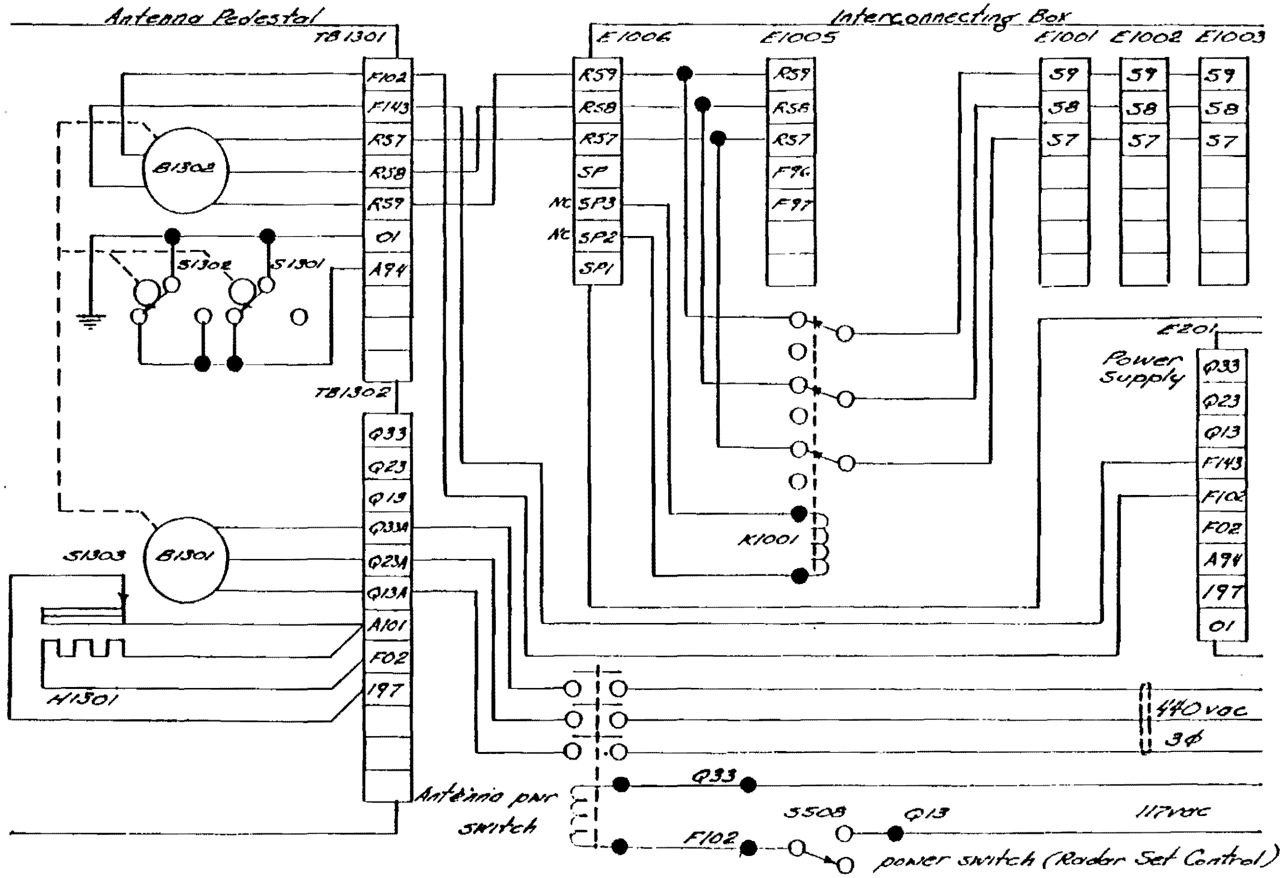


Figure 14. Antenna Pedestal to SPS-10 Radar Interconnection.

II. TELEPHONE SCHEMATIC AND THEORY

To provide communications between the radar enclosure mounted on the roof of Building 110 and the operator at the SPA-25 indicator, EES developed a telephone intercom system to assist in trouble-shooting and instrument adjustment. The assembly of this system is described in the following paragraphs and figures.

When the telephone handpiece is picked up, automatic circuitry activites the ring voltage on the telephone on the opposite end. With the lifting of the handpiece on the other phone, the talk path is completed.

The +150 volt supply provides current for the relay operation and telephone. The +10 volt supply provides voltage to operate the ring circuit generator. Current to the telephones is limited to 20 milliamperes by the parallel circuit of the relay and 1.5 K ohm resistor. The ring tone is generated in the MC3456 (NE556) integrated circuit. The ring time is a 20 Hz tone cycled on for 1 second, off for 2 seconds. The MPS-U60 transistor level shifts the ring tone into the telephone system.

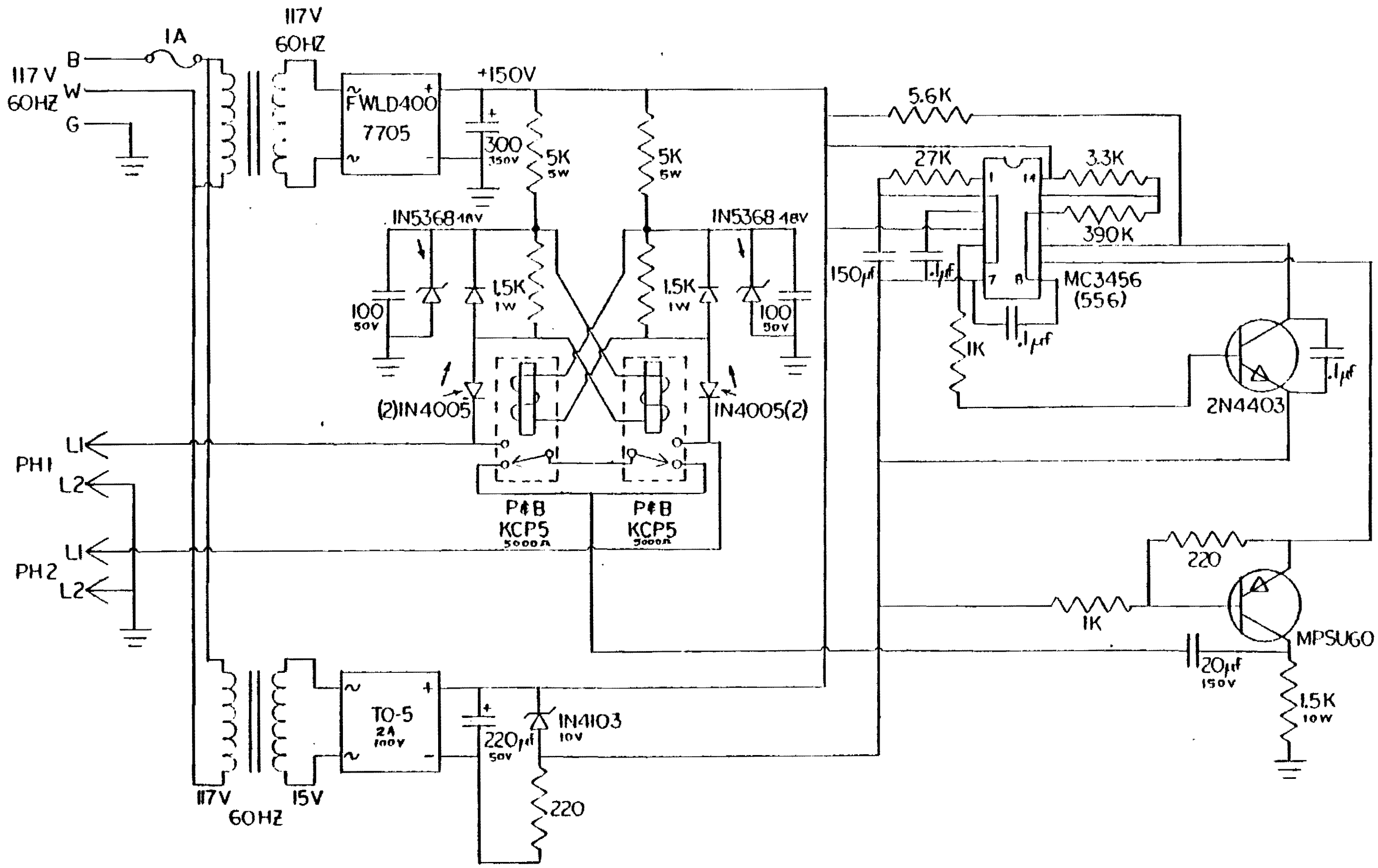


Figure 15. Telephone Schematic.

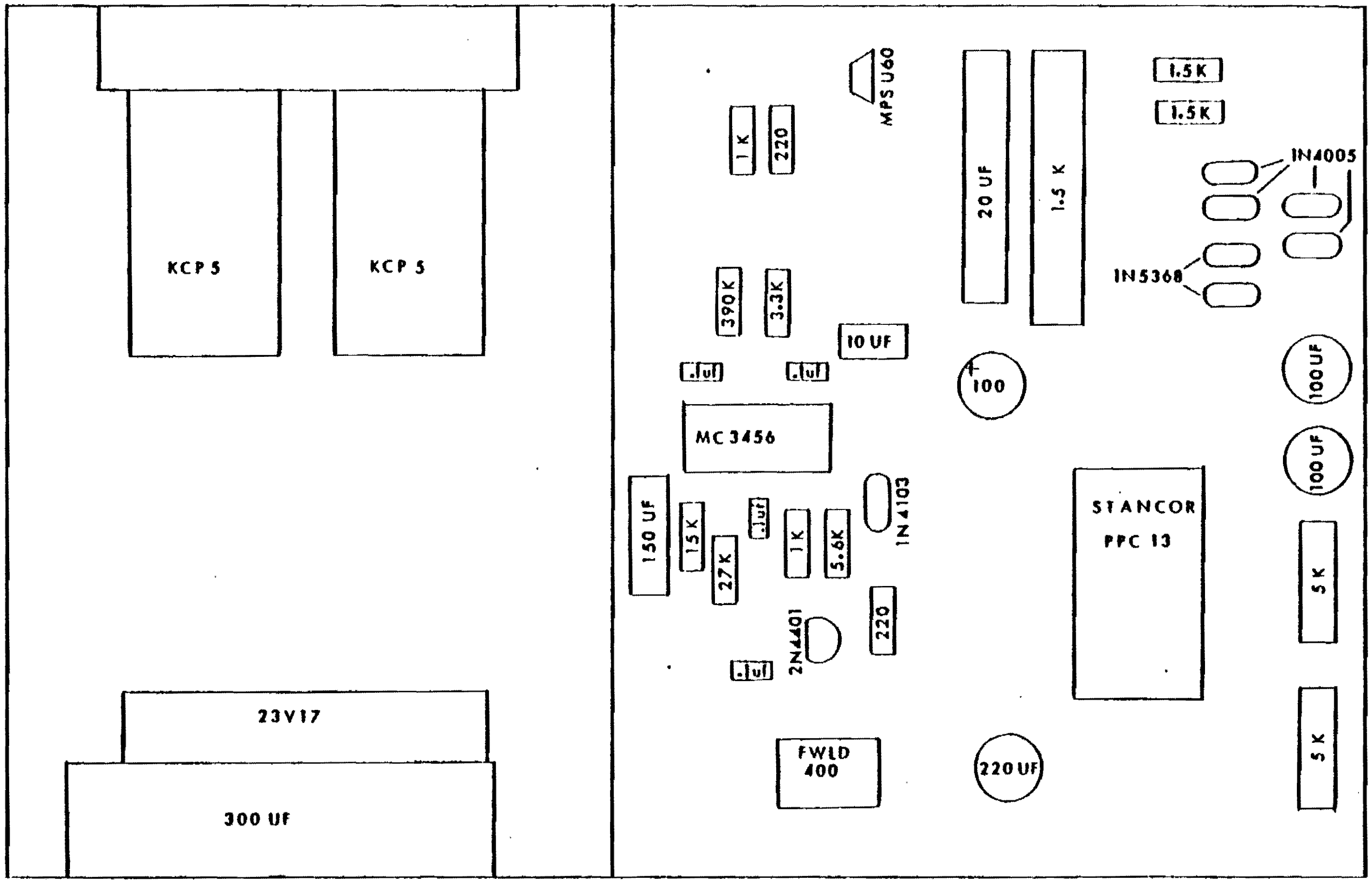


Figure 16. Telephone Component Layout.

III. TM-503 INTERNAL WIRING FOR SAMPLERS

FROM	TO
J-10-A-14	J-20-A-14 shield
J-10-A-15	J-20-A-14 -
J-10-A-16	J-20-B-16
J-10-A-28	J-20-A-28
J-10-B-14	J-20-B-14 shield
J-10-B-15	J-20-B-15 -
J-10-B-16	J-20-B-16
J-10-B-28	J-20-B-28
J-20-A-14	J-10-A-14
J-20-A-15	J-10-A-14
J-20-A-16	J-10-A-14
J-20-A-18	J-1-1
J-20-A-19	J-1-3
J-20-A-20	J-1-5
J-20-A-21	Back Panel Jack C Shield
J-20-A-22	Back Panel Jack B Left Shield
J-20-A-23	Back Panel Jack B Right Shield
J-20-A-24	Back Panel Jack B
J-20-A-25	Back Panel Jack A Left Shield
J-20-A-26	Back Panel Jack A Right Shield
J-20-A-27	Back Panel Jack A Shield
J-20-A-28	J-10-A-14
J-20-B-14	J-10-B-14
J-20-B-15	J-10-B-15
J-20-B-16	J-10-B-16
J-20-B-18	J-1-2
J-20-B-19	J-1-4
J-20-B-20	J-1-6
J-20-B-21	Back Panel Jack C

J-20-B-22	Back Panel Jack B Left
J-20-B-23	Back Panel Jack B right
J-20-B-24	Back Panel Jack B
J-20-B-25	Back Panel Jack A Left
J-20-B-26	Back Panel Jack A Right
J-20-B-27	Back Panel Jack A
J-20-B-28	J-10-A-14

SAMPLERS REAR PANEL JACK IDENTIFICATION